Table 1. The Berea sandstone core properties

| Core # | $D_c$, cm | L, cm | $K_g$, md | $\phi$, % | $S_{wi}$,% | $\mu_o$, cp | Wetness |
|---|---|---|---|---|---|---|---|
| Soltrol 220, no aging | | | | | | | |
| Ev8h8b | 3.764 | 7.91 | 73.9 | 0.1615 | 22.6 | 3.8 | VSWW |
| Ev8h9a | 3.739 | 8.057 | 82.9 | 0.1601 | 20.9 | 3.8 | VSWW |
| Ev8h9b | 3.742 | 7.922 | 76.7 | 0.1588 | 24.6 | 3.8 | VSWW |
| Ev8h10a | 3.761 | 8.047 | 76.7 | 0.1636 | 22.7 | 3.8 | VSWW |
| Ev8h10b | 3.764 | 7.83 | 70.1 | 0.1627 | 22.5 | 3.8 | VSWW |
| Ev8h17a | 3.763 | 8.245 | 77.4 | 0.1734 | 22.59 | 3.8 | VSWW |
| Ev8h18a | 3.753 | 7.894 | 95.8 | 0.1746 | 23.02 | 3.8 | VSWW |
| Minnelusa 2002 crude oil | | | | | | | |
| Ev8h1a | 7.864 | 3.786 | 101.5 | 0.1760 | 23.9 | 68.0 | MXW, 10d aging |
| Ev8h2b | 7.538 | 3.765 | 71.7 | 0.1652 | 23.7 | 68.0 | MXW, 10d aging |
| Ev8h3a | 3.764 | 7.963 | 70.1 | 0.1678 | 24.3 | 1.5 | MXW-F (Dakota) , 10d aging |
| Ev8h4a | 3.764 | 8.06 | 65.1 | 0.1636 | 24.3 | 68.0 | MXW, 10d aging |
| Ev8h4b | 7.680 | 3.767 | 66.6 | 0.1628 | 24.6 | 680 | MXW, 1d aging |
| Ev8h5a | 8.242 | 3.764 | 68.2 | 0.1649 | 24.6 | 68.0 | MXW, no aging |
| Ev8h5b | 3.766 | 7.754 | 74.6 | 0.1664 | 24.4 | 3.8 | MXW-F (S220), no aging |
| Ev8h6b | 7.736 | 3.764 | 67.6 | 0.1605 | 22.0 | 68.0 | MXW, 10d aging |
| Ev8h7b | 3.765 | 7.67 | 72.4 | 0.1603 | 22.5 | 1.5 | MXW-F (Dakota) , no aging |
| Ev8h11b | 3.758 | 7.791 | 120 | 0.1743 | 22.8 | 1.5 | MXW (Dakota) , no aging |
| Ev8h13a | 3.758 | 8.105 | 126.2 | 0.1754 | 23.2 | 68.0 | MXW, no aging |
| Ev8h16a | 8.280 | 3.759 | 114.0 | 0.1778 | 22.1 | 68.0 | MXW, 10d aging |
| Ev8h16b | 3.76 | 7.921 | 117.2 | 0.1774 | 21.3 | 68.0 | MXW, 10d aging |
| Ev8h29a | 3.75 | 8.262 | 133.1 | 0.1749 | 18.8 | 68.0 | MXW, 4d aging, 45°C |
| Ev7v1b | 7.644 | 3.788 | 58.2 | 0.1748 | 23.3 | 68.0 | MXW, 10d aging |
| Ev1v1d | 3.777 | 7.581 | 46.2 | 0.1703 | 22.0 | 68.0 | MXW, 10d aging |
| Ev5h1c | 3.787 | 7.634 | 113 | 0.182 | 23.9 | 68.0 | MXW, 10d aging |
| Tensleep 95 crude oil | | | | | | | |
| Ev8h13b | 3.758 | 7.835 | 119.3 | 0.1731 | 21.3 | 19.2 | MXW, 10d aging |
| Ev8h14a | 3.759 | 8.076 | 109.6 | 0.1717 | 22.6 | 19.2 | MXW, no aging |
| Ev8h14b | 3.76 | 7.839 | 106.2 | 0.1708 | 22.0 | 1.5 | MXW-F (Dakota) , no aging |
| Ev8h15a | 3.757 | 8.228 | 111.1 | 0.1778 | 22.2 | 1.5 | MXW-F (Dakota) , no aging |
| Ev8h15b | 3.759 | 7.974 | 114.4 | 0.1776 | 22.7 | 19.2 | MXW , no aging |
| Ev8h21b | 3.758 | 7.686 | 87.6 | 0.174 | 22.6 | 33.9 | MXW-F (frontier) , no aging |
| Big Sand Draw crude oil | | | | | | | |
| Ev8h19a | 3.756 | 7.866 | 70.9 | 0.1698 | 23.1 | 3.8 | MXW-F (S220) , no aging |
| Ev8h21a | 3.758 | 7.832 | 84.8 | 0.1724 | 23.3 | 7.0 | MXW, no aging |
| Ev8h27b | 3.750 | 7.758 | 119.7 | 0.1741 | 23.6 | 7.0 | MXW , no aging |
| Ev8h28b | 3.750 | 8.056 | 121.2 | 0.1794 | 22.3 | 7.0 | MXW, 10d aging |
| Ev8h30a | 3.748 | 7.597 | 86.8 | 0.1705 | <24.7 | 7.0 | MXW, 2d aging |
| Ev8h30b | 3.752 | 7.153 | 86 | 0.1717 | <26.3 | 7.0 | MXW, 2d aging |

Table 2. The Limestone core properties

| Core # | D, cm | L, cm | $K_g$, md | $\phi$, % | $S_{wi}$,% | $\mu_o$, cp | Wetness |
|---|---|---|---|---|---|---|---|
| Oil recovery (Cottonwood oil) | | | | | | | |
| 1TC15a | 3.724 | 7.477 | 19.1 | 0.2696 | 24.3 | 24.1 | MXW, 10d aging |
| T2Tc11a | 3.729 | 7.320 | 14.7 | 0.2767 | 18.59 | 24.1 | MXW, 10d aging |
| T2Tc21a | 3.698 | 7.797 | 7.1 | 0.2300 | 22.12 | 24.1 | MXW, 10d aging |
| Gas flooding | | | | | | | |
| 1TC8b | 3.734 | 6.59 | 3.7 | 18.0 | 100 | | VSWW |
| 1TC20b | 3.749 | 7.452 | 6.1 | 21.6 | 100 | | VSWW |
| 1TC24b | 3.753 | 7.593 | 3.6 | 18.0 | 100 | | VSWW |
| 3TC18b | 3.740 | 6.490 | 1.4 | 20.2 | 21.4 | | VSWW |
| 2TC4b | 3.788 | 6.481 | 3.4 | 22.8 | 21.7 | | Tensleep/S130, 2d aging |
| 1TC24b | 3.753 | 7.593 | 3.6 | 18.0 | 27.5 | | BS oil (the 2nd and 3rd cycle), 2d aging |

Table 3. Selected properties of crude and refined oils

| Oils | | $\rho$, g/mL @20°C | $\eta$, cP @~22°C | IFT, mN/M @20°C | Asphalt.% |
|---|---|---|---|---|---|
| Asphaltic crudes | Minnelusa 2002 | 0.9076 | 68 | 23.4 | 9.5 |
| | Black Mt. | 0.9219 | 134 | | 8.1 |
| | Tensleep 95 | 0.8692 | 19.2 | 23.3 | 3.2 |
| | Cottonwood | 0.8874 | 24.1 | 28.9 | 2.3 |
| | Big Sand Draw | 0.8496 | 7.0 | 21.5 | 1.6 |
| Mineral oils | S220 | 0.7869 | 3.8 | 49.5 | 0 |
| | S130 | 0.7605 | 1.6 | ~50 | 0 |
| | Pentane | | | ~50 | 0 |
| Paraffinic crudes | Dakota | 0.7741 | 1.5 | 34.2 | 0 |
| | Frontier | 0.8338 | 21.8 | 33.8 | 0 |

Table 4. Synthetic brine composition

| Brine | NaCl (g/L) | KCl (g/L) | $CaCl_2$ (g/L) | $MgCl_2$ (g/L) | $NaN_3$ (g/L) | pH | TDS (mg/L) |
|---|---|---|---|---|---|---|---|
| Sea water | 28 | 0.935 | 2.379 | 5.365 | 0.1 | 6.6 | 36779 |

Table 5 Interfacial tensions (Aqueous phase = SSW)

| Oleic phase | IFT, mN/m | Temp.,°C |
|---|---|---|
| S220 | 49.5 | 20.0 |
| S220 | 1.7 | 20.0 |
| S220+0.025%polyamine | 24.3 | 20.0 |
| S220+0.2%RAP | 0.03 | 20.0 |
| S220+0.05%RAP | 0.55 | 20.0 |
| S220+0.025%PA+0.05%RAP | 1.0 | 20.0 |
| S220+0.2%TDA-6 | 1.34 | 20.0 |
| S220+0.1%DA-4 | 11.7 | 20.0 |
| S220+0.1%oleic acid | 29.8 | 20.0 |
| Minnelusa 2002 crude oil | 23.4 | 20.0 |
| Dakota crude oil | 34.2 | 20.0 |
| Tensleep 1995 crude oil | 23.3 | 20.0 |
| Big SandDraw crude oil | 21.5 | 20.0 |
| Frontier crude oil | 33.8 | 20.0 |
| M'02 +0.025%PA | 17.7 | 20.0 |
| M'02+0.05%RAP | 8.6 | 20.0 |
| Dakota oil+0.025%PA | 7.9 | 20.0 |
| Tensleep 95 +0.05%PA | 10.5 | 20.0 |
| BS oil +0.05%PA | 10 | 20.0 |
| BS oil + 0.1%PA | 7.2 | 20.0 |
| BS oil + 0.1%PA | 4.3 | 75.0 |
| Cottonwood oil +0.025% PA | 12.1 | 20.0 |
| Cottonwood oil | 28.9 | 20.0 |

Table 6 Asphaltene precipitation

| | Minnelusa crude | Black Mountain crude | Tensleep crude | Big Sand Draw |
|---|---|---|---|---|
| S220 or S130 | Yes | Yes | Yes | Yes |
| Dakota oil | Yes | Yes | Yes | Yes |
| Frontier oil | | Yes (under microscope) | No | No |

**Fig. 1 Method 1 of treatment for oil reservoir case**

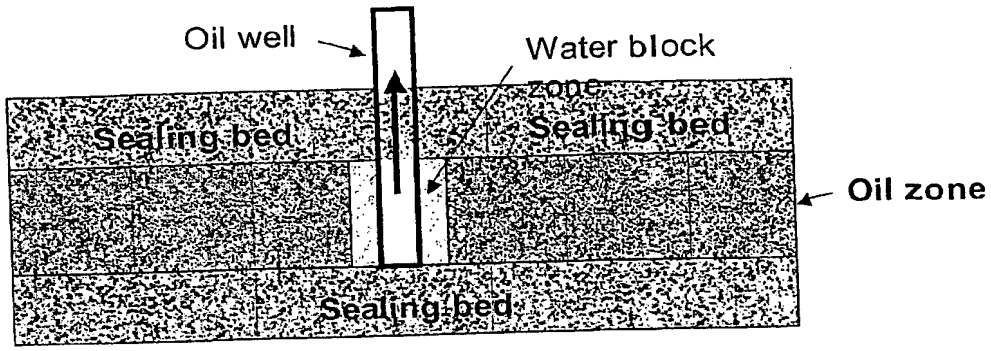



Fig.1a

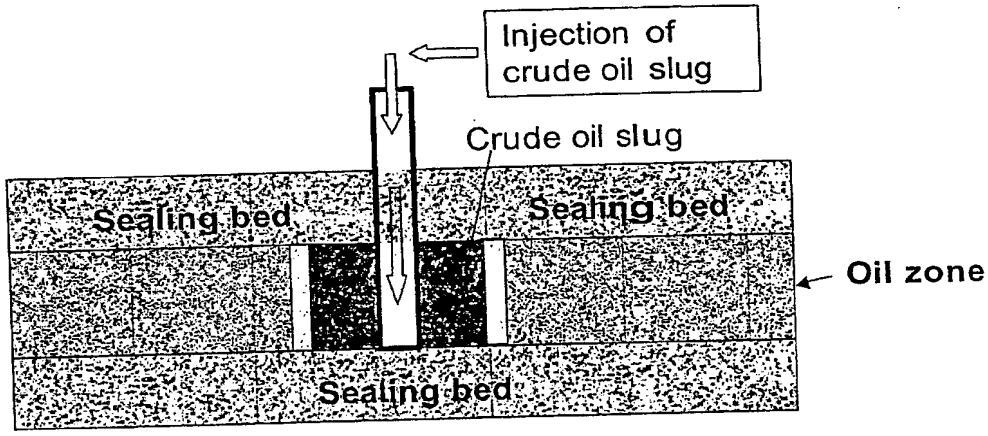



Fig.1b

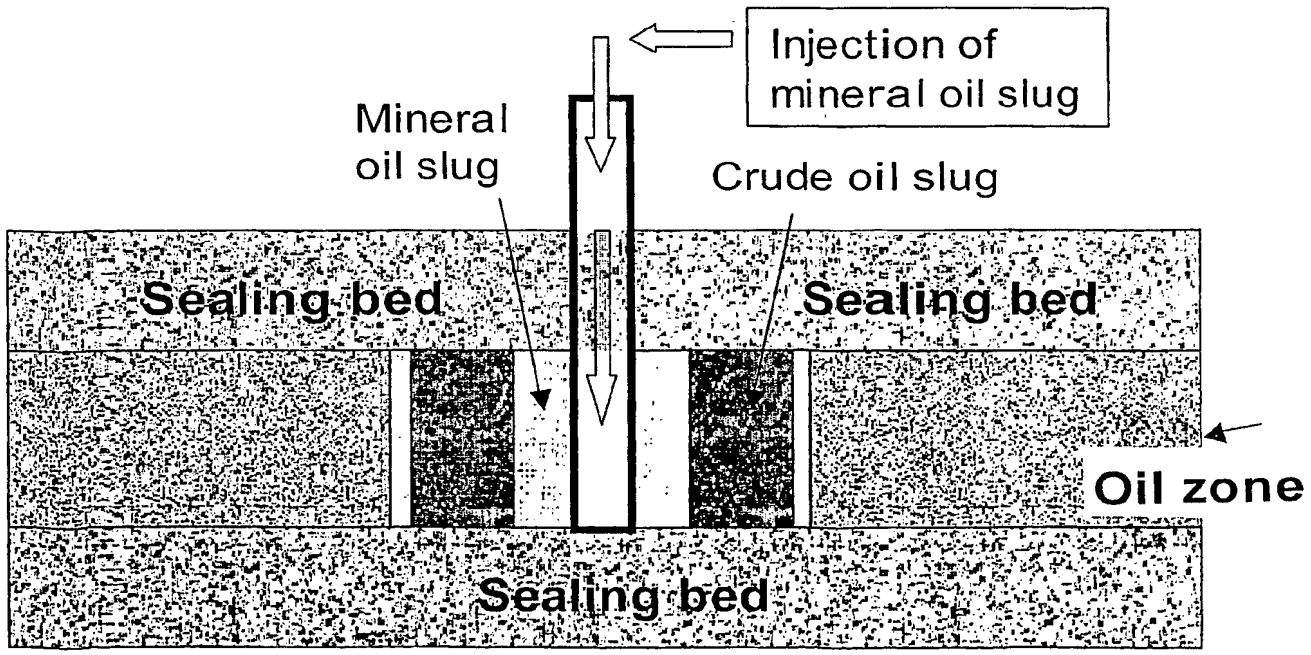



Fig.1c

Fig.1d

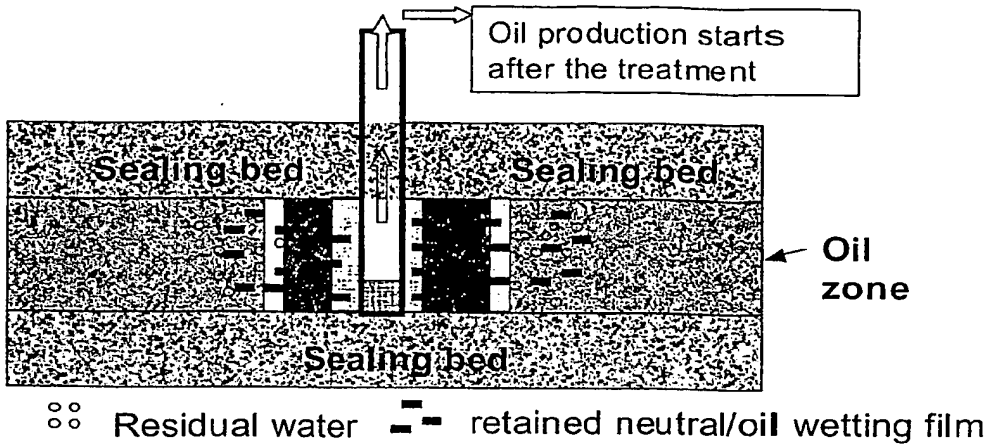



Fig.1e

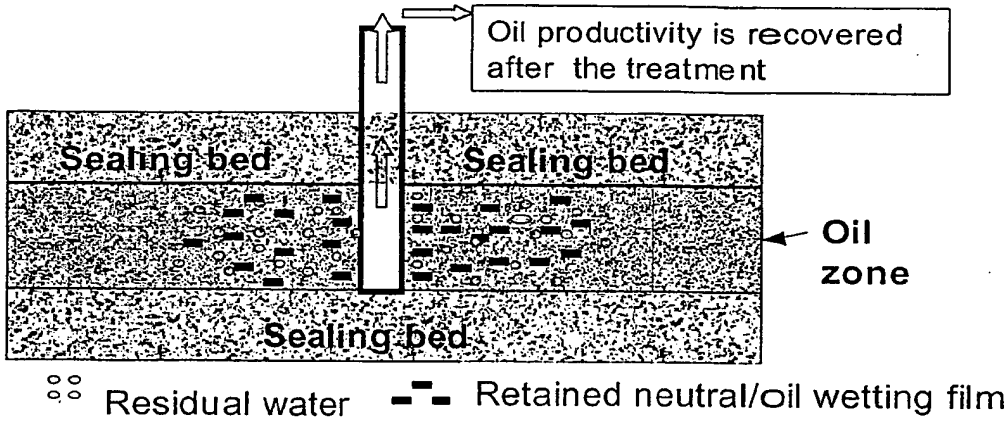



**Fig. 2 The sketch of water saturation change near well bore vs. cycle numbers of treatment**

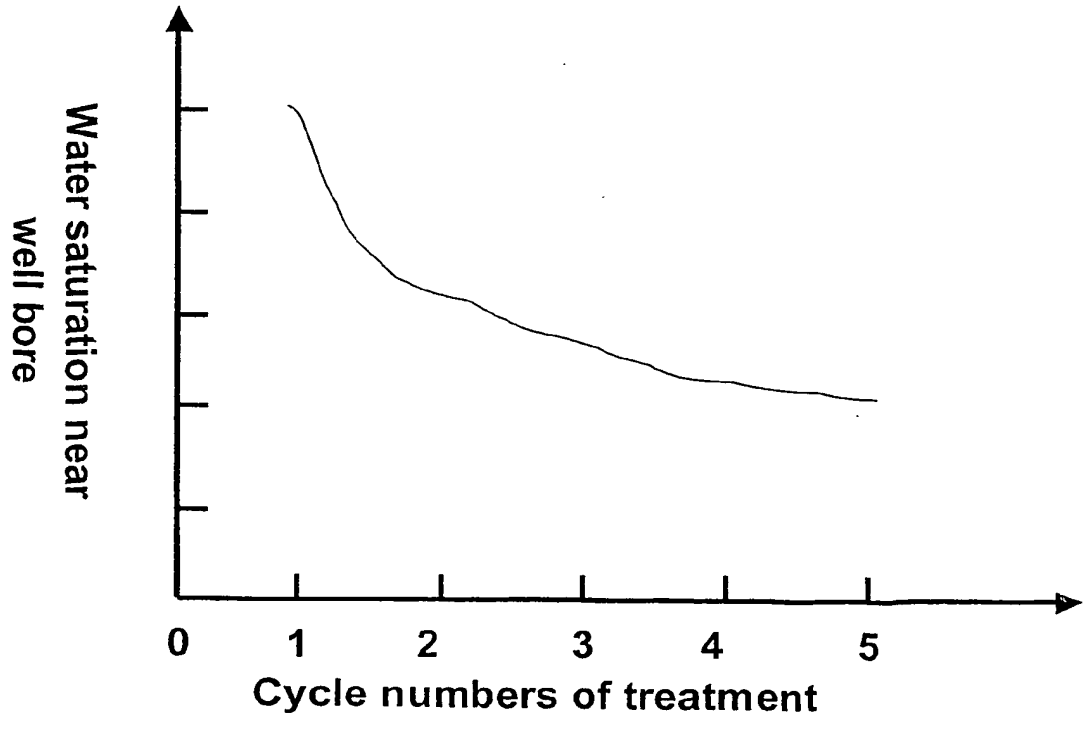


**Fig. 3 Method 2 of treatment for oil reservoir case**

Fig.3a

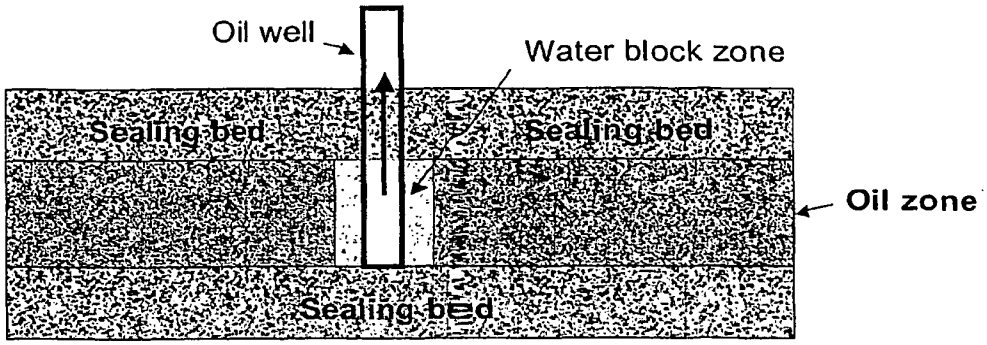



Fig.3b

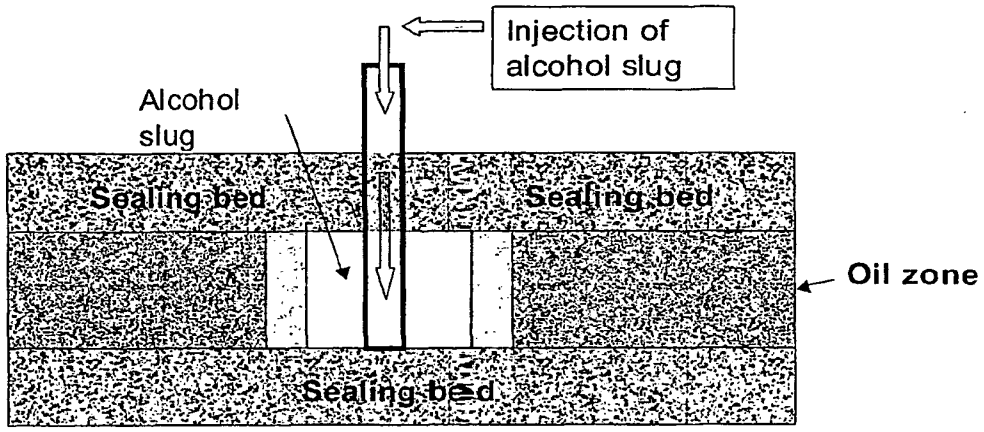



Fig.3c

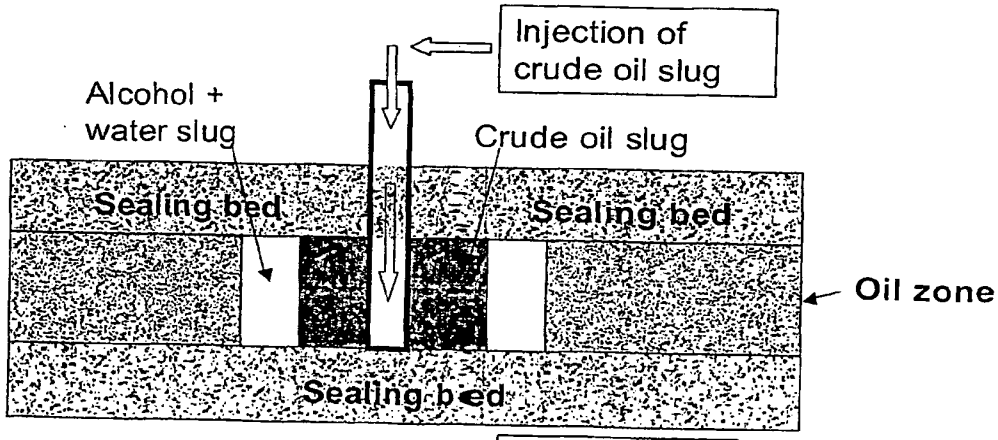
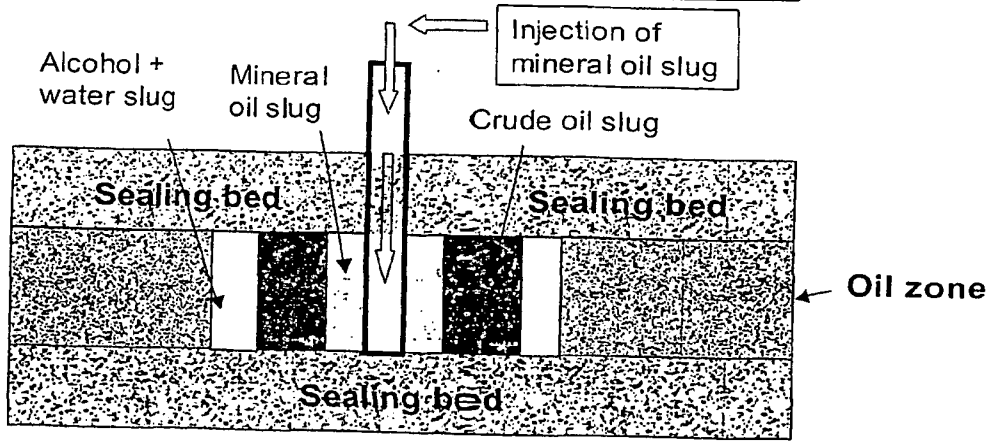



Fig.3d



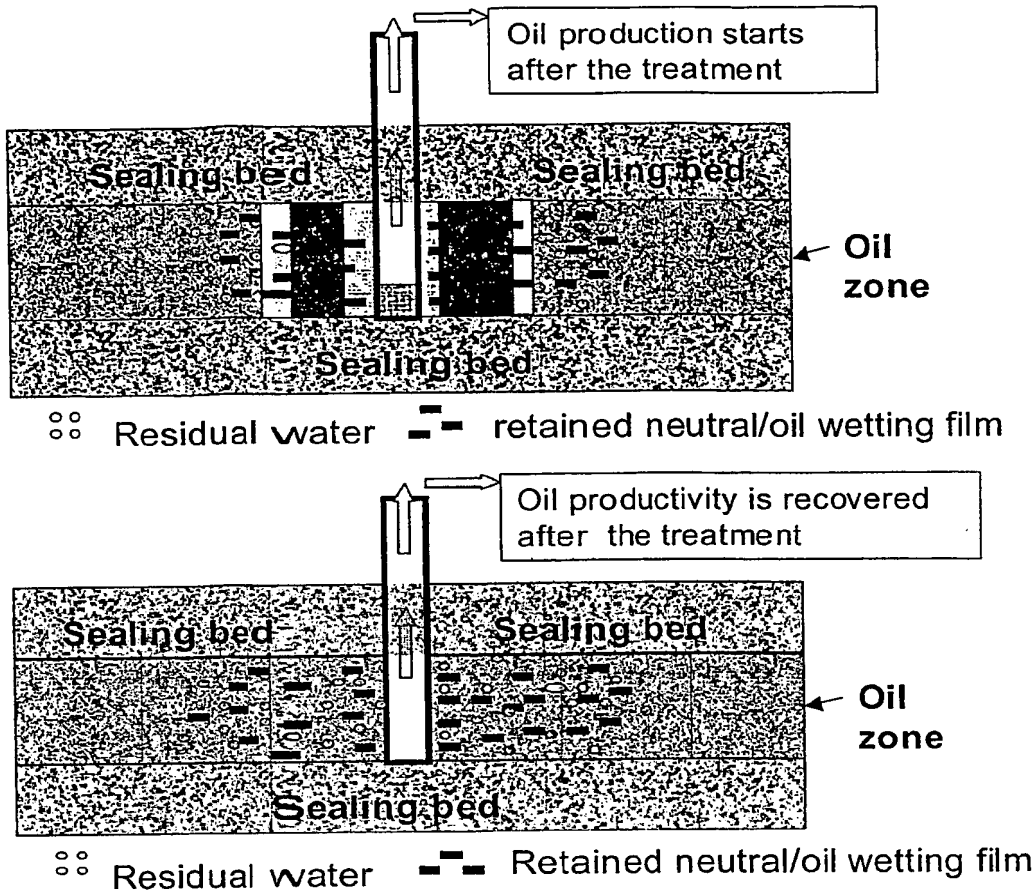



Fig.3e

Fig.3f

**Fig. 4 Method 1 of treatment for gas or gas condensate reservoir case**

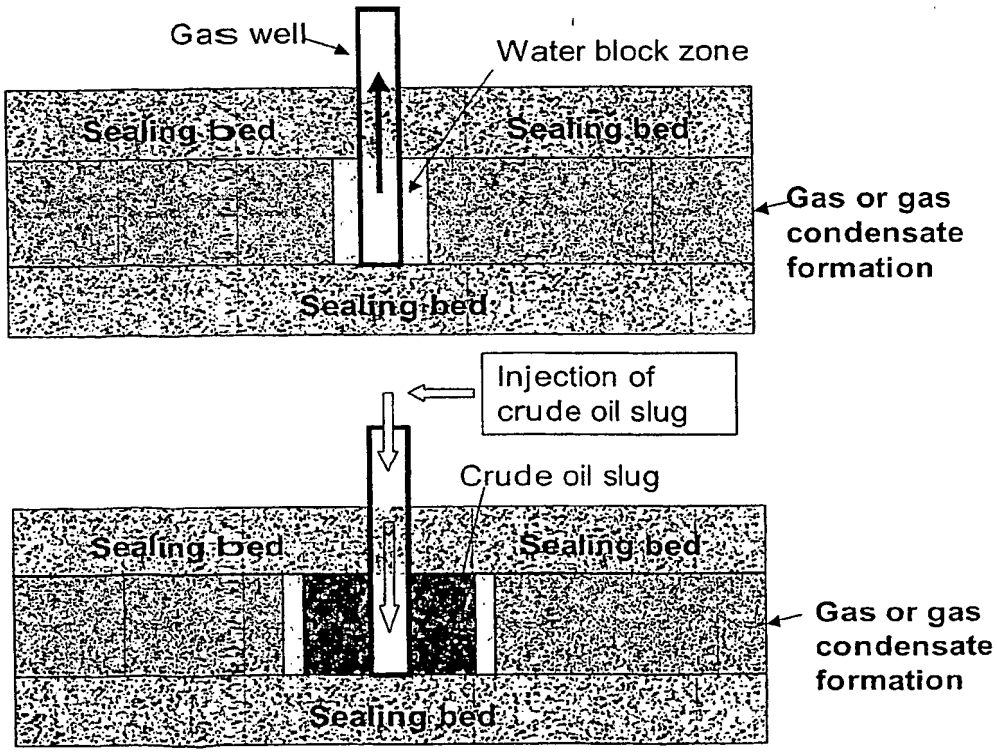



Fig.4a

Fig.4b

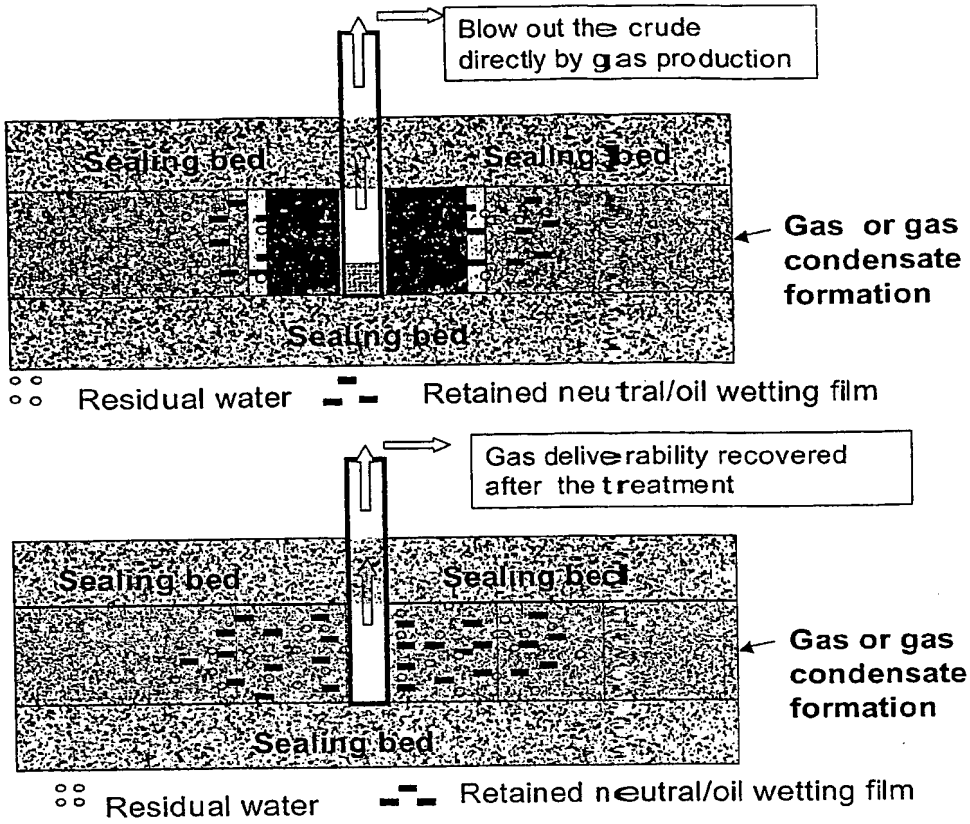



Fig.4c

Fig. 4d

**Fig. 5 Method 2 of treatment for gas or gas condensate reservoir case**

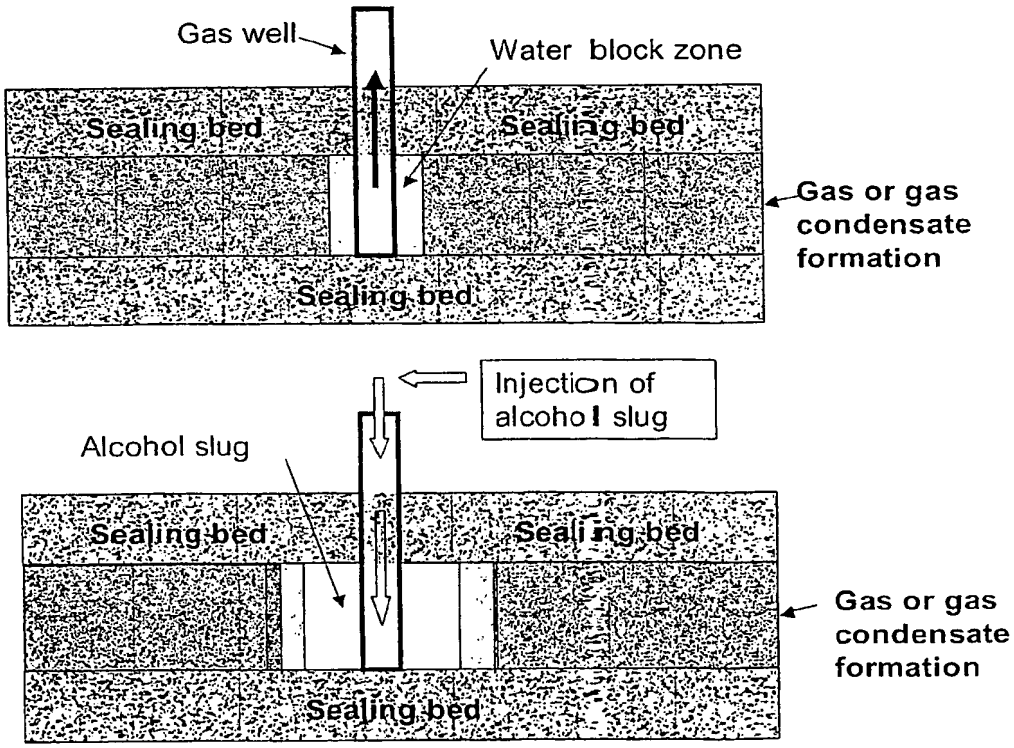



Fig.5a

Fig.5b

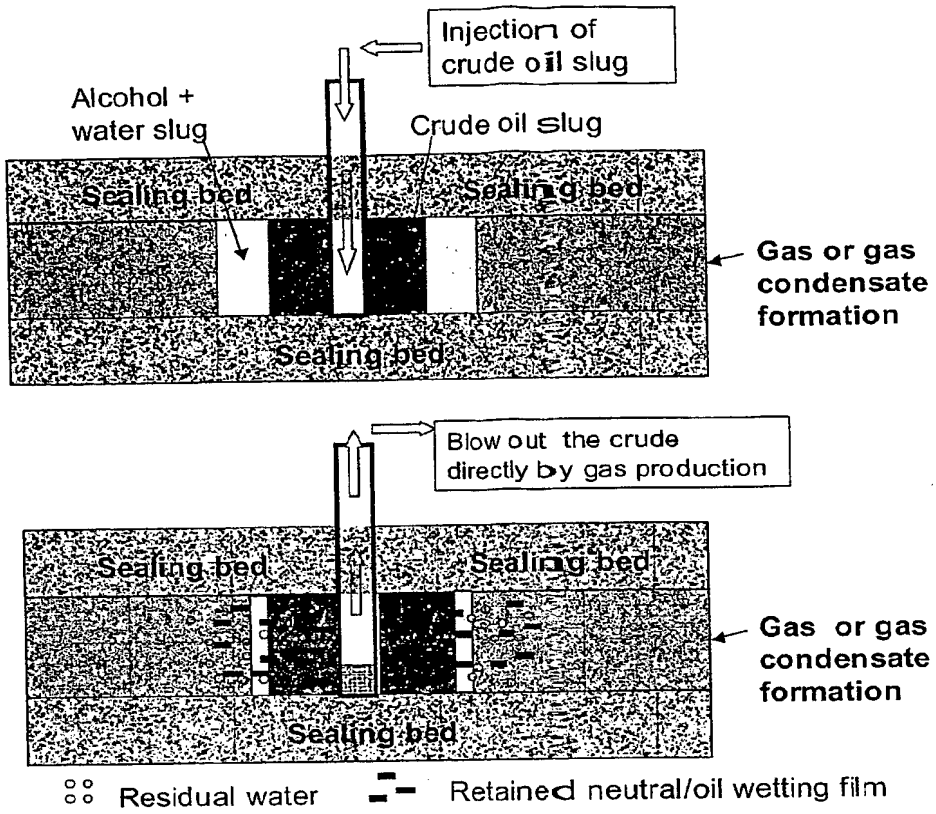



Fig.5c

Fig.5d

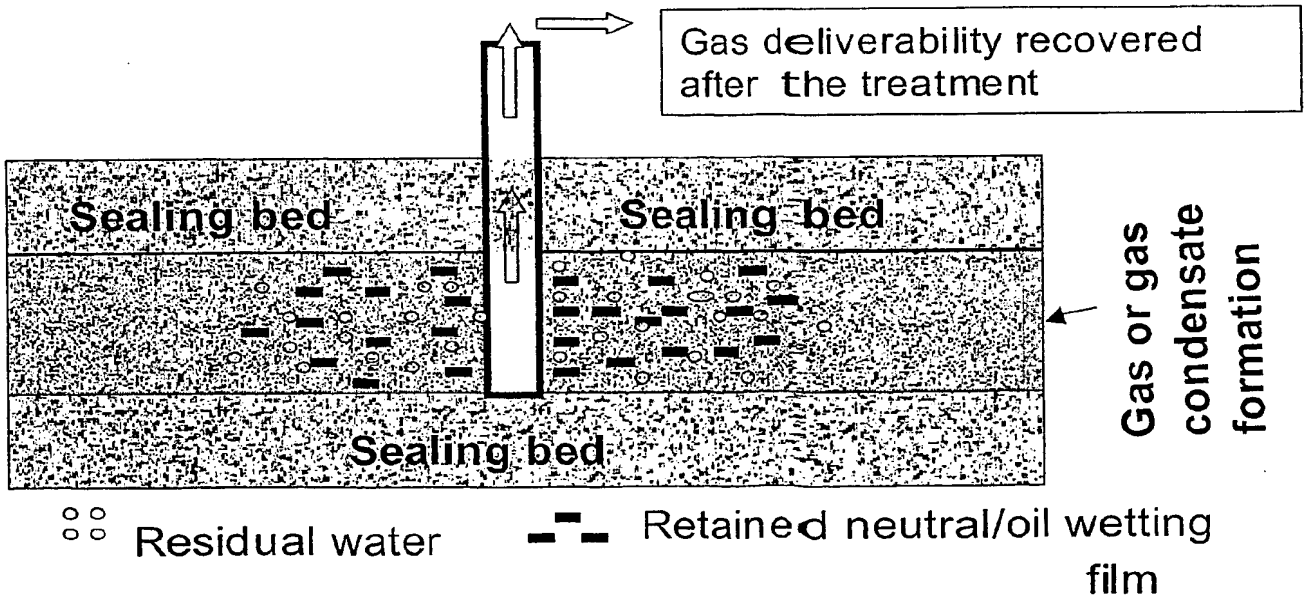



Fig. 5e

**Fig. 6 Method 3 of treatment for gas or gas condensate reservoir case**

Fig.6a

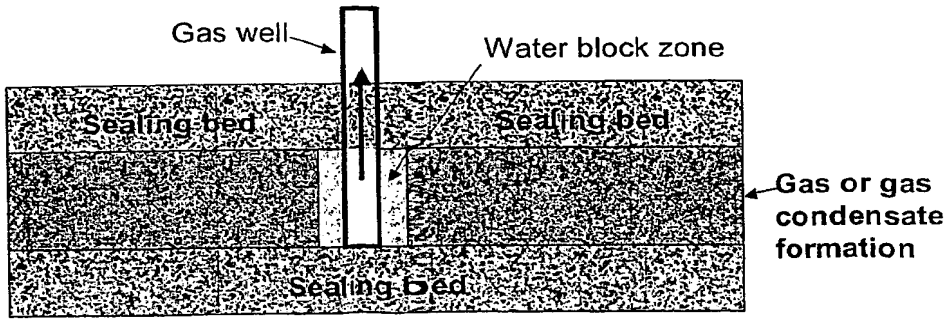



Fig.6b

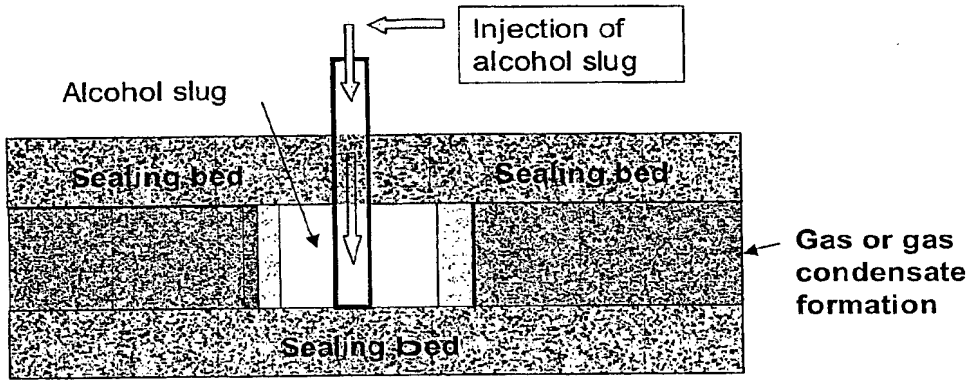



Fig. 6c

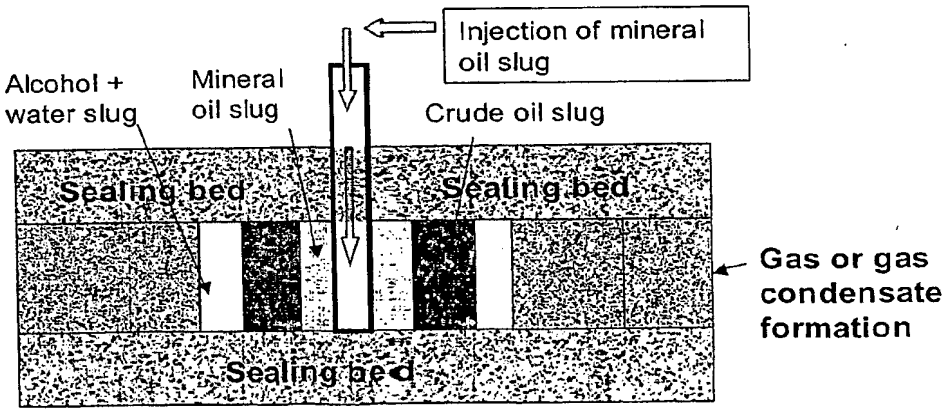
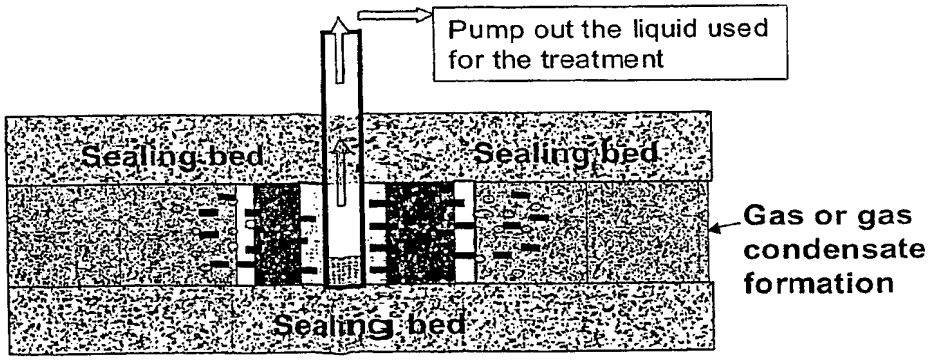



Fig. 6d



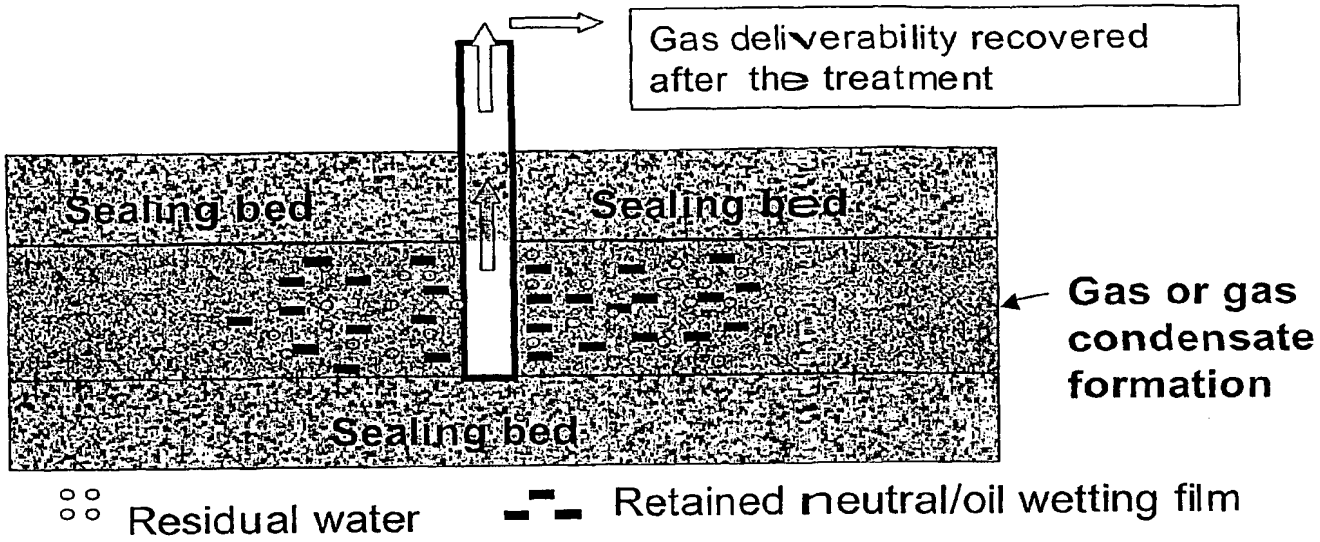



Fig. 6e

Fig. 7 Water coning case

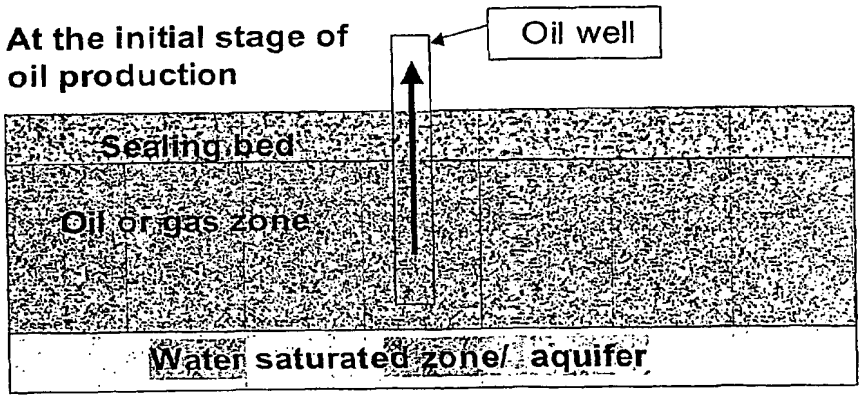



Fig. 7a

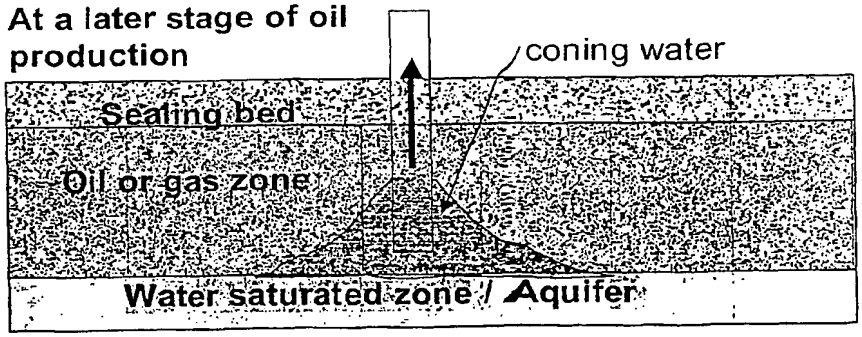
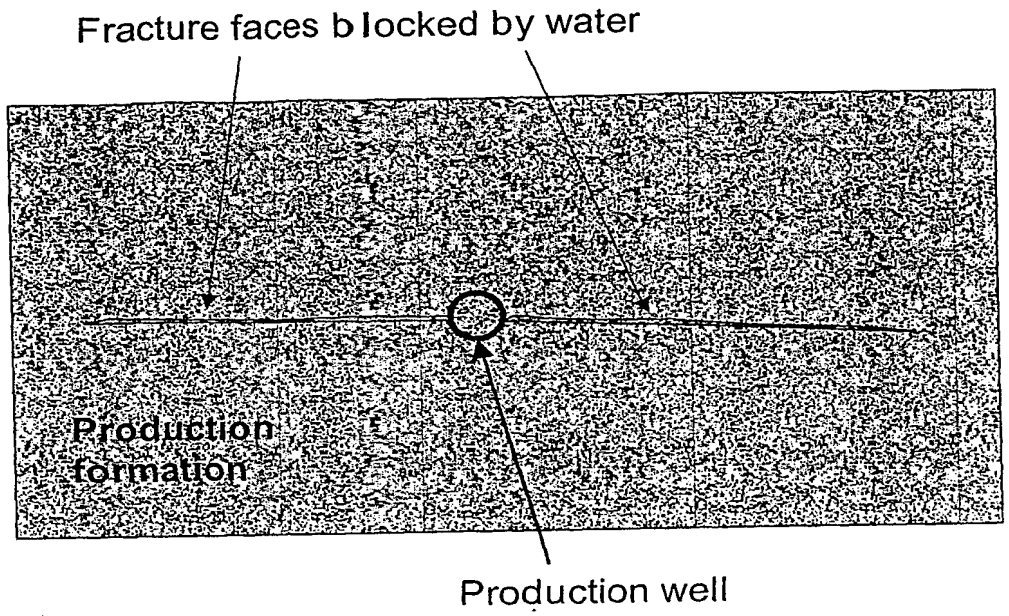
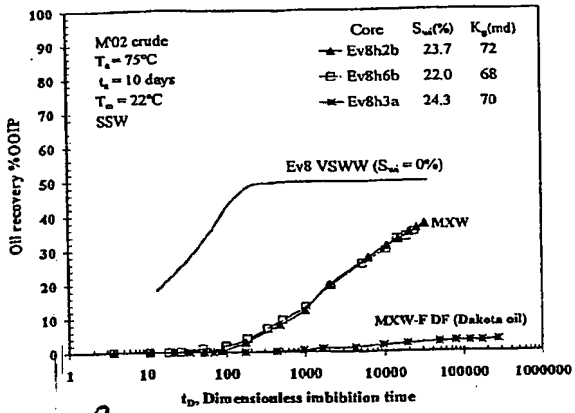


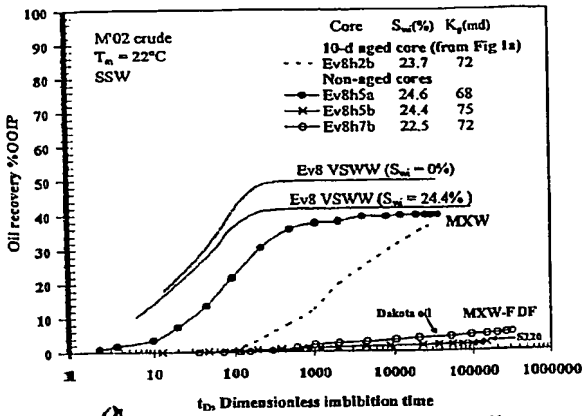

Fig. 7b

Fig. 8 Case with hydraulic fracture wells—plane view sketch

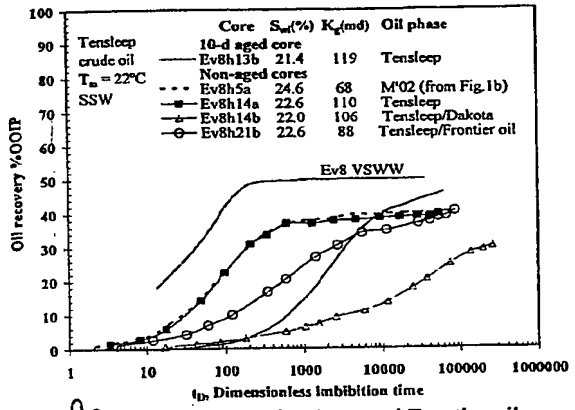




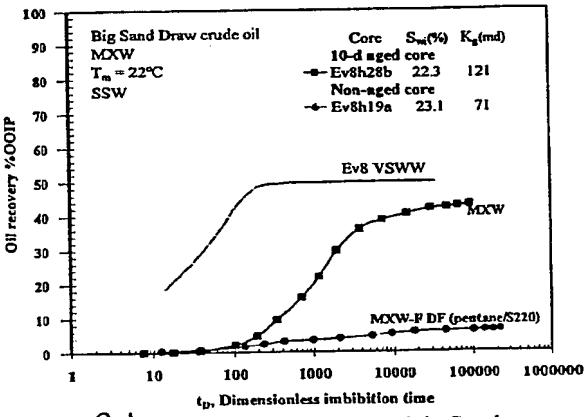

9a. Dakota oil displacing M'02 crude after 10-day aging




9b Comparison of S220 and Dakota oil displacing M'02 crude without aging




9c Comparison of Dakota and Frontier oil displacing Tensleep crude without aging




9d Pentane/S220 displacing Big Sand Draw crude without aging

Fig. 9 Wettability alteration was induced by displacement of crude oil with mineral oil or paraffinic oil directly.

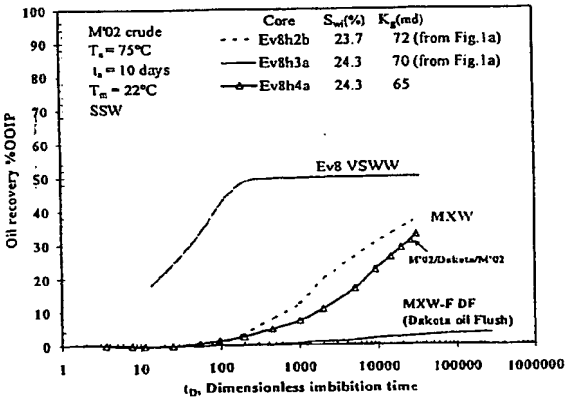
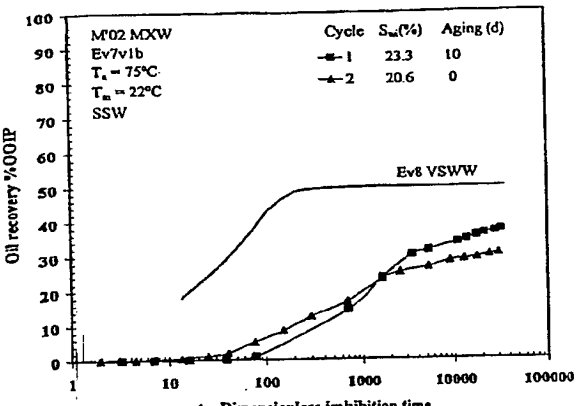
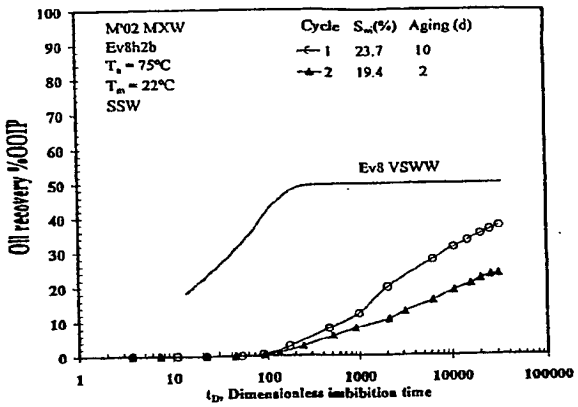



Fig. 10 Re-exposing surface-precipitated asphaltenes to fresh crude oil resulted in increased water wetness.

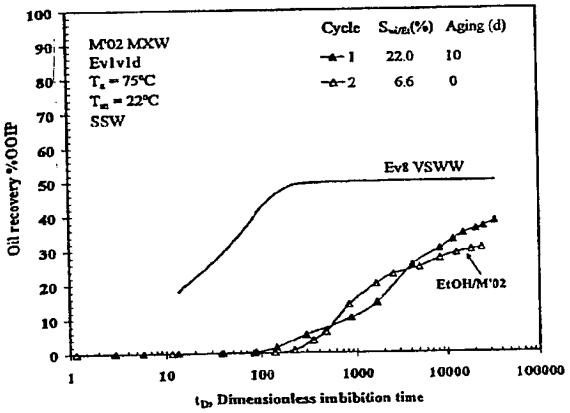



16a Cyclic imbibition without re-aging

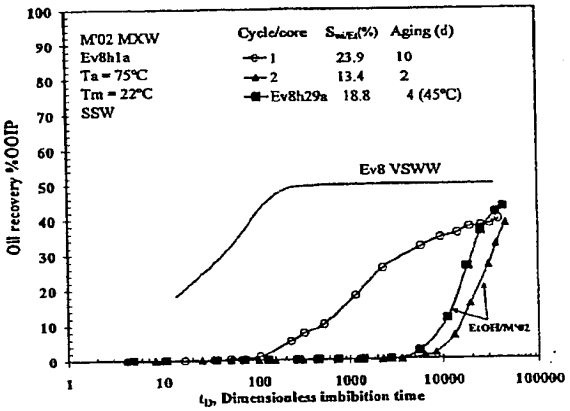



16b Cyclic imbibition with re-aging

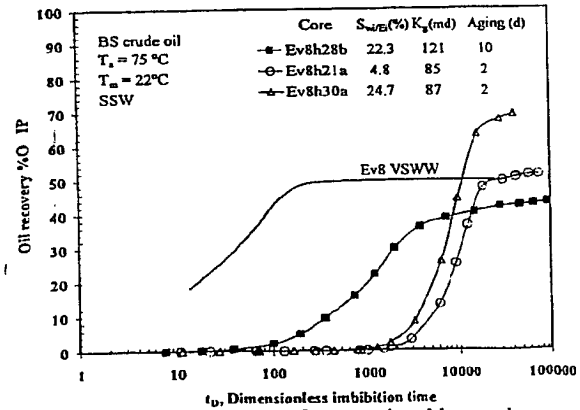
Figure 16. The effect of re-aging on wettability alteration




12a Cyclic imbibition of M'02 crude without re-aging

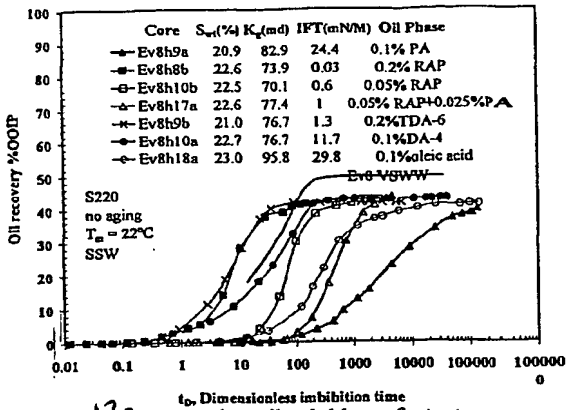



12b Cyclic imbibition of M'02 crude with re-aging

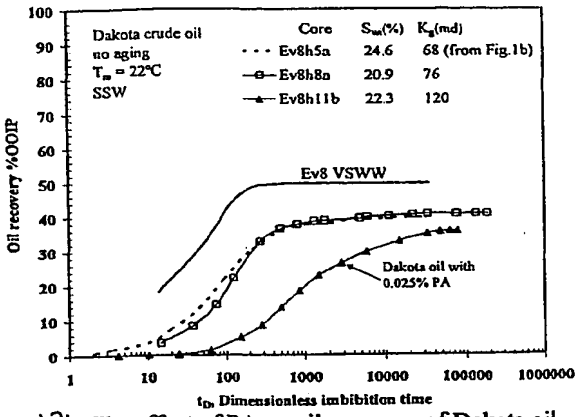



12c Cyclic imbibition of BS crude with re-aging

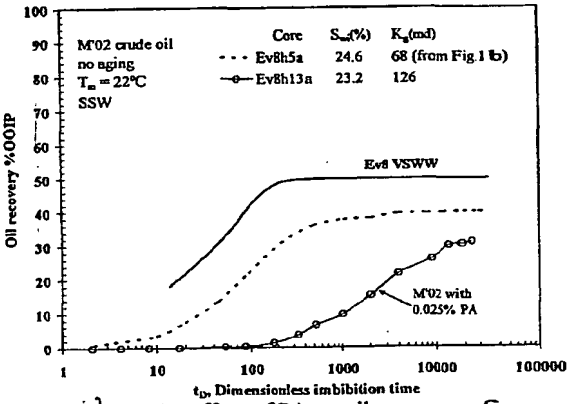
Fig 12 The effect of alcohol flush and re-aging on wettability alteration



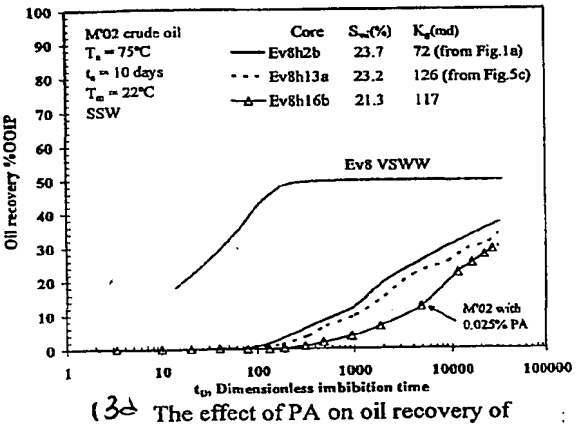

13a Screening oil-soluble surfactants



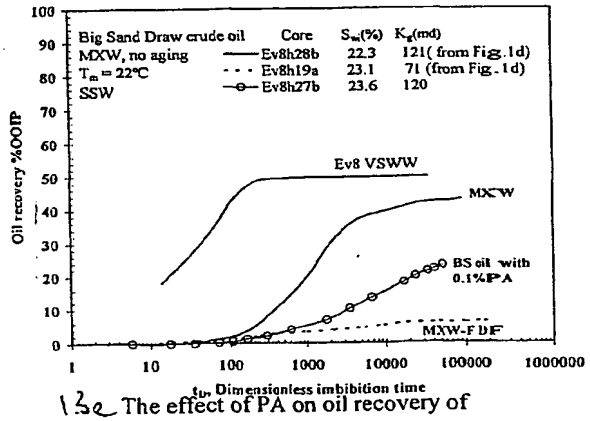

13b The effect of PA on oil recovery of Dakota oil



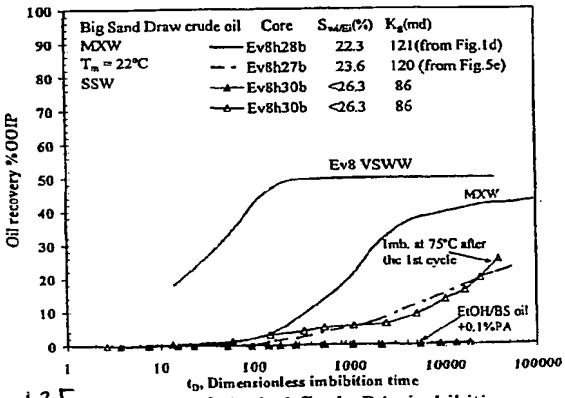

13c The effect of PA on oil recovery of M'02 without aging




13d The effect of PA on oil recovery of M'02 with aging




13e The effect of PA on oil recovery of BS oil without aging




13f The effect of alcohol flush, PA, imbibition temperature on oil recovery of BS oil without aging

FIG. 13 The effect of alcohol flush, oil-soluble surfactant and re-aging on wettability alteration for Berea sandstones

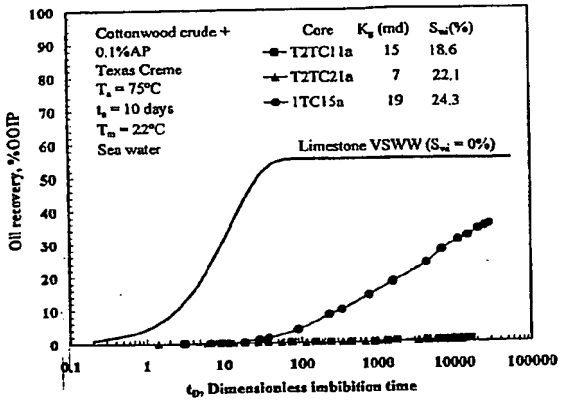
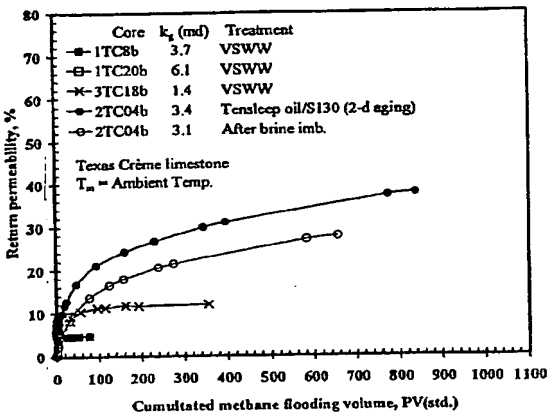
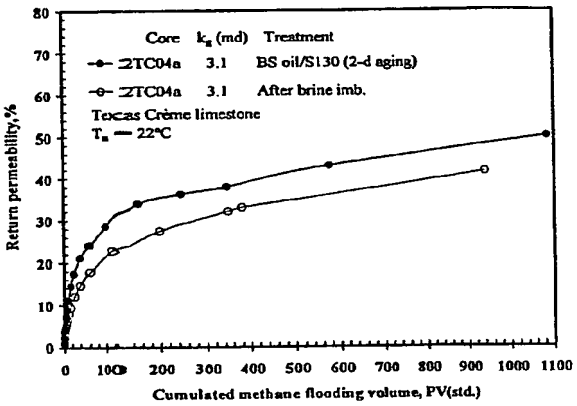


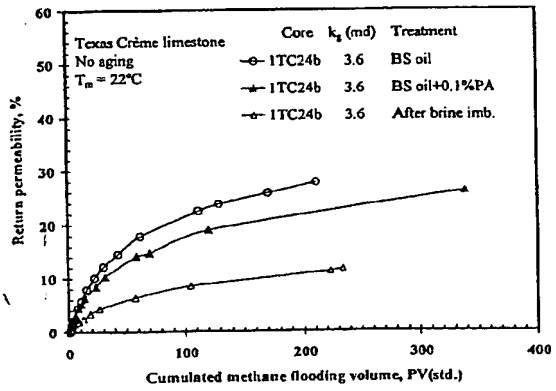

Fig. 14 The effect of Cottonwood crude oil and oil-soluble surfactant on wettability alteration for limestone



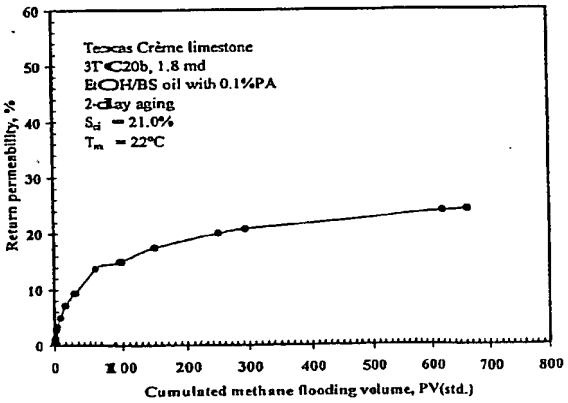

15a. Comparison between VSSW and Wettability induced by Tensleep/S130 with 2-d aging




15b Wettability induced by BS oil/S130 with 2-d aging




15c Wettability altered by BS oil or BS oil+0.1%PA without aging




15d Wettability altered by alcohol flush and BS oil+0.1%PA with 2-d aging

Fig. 15 The effect of wettability alteration on gas return permeability